Study On The Rock Quality Designation (RQD) And Groundwater Cavity Of The Kuala Lumpur Limestone Formation

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Study On The Rock Quality Designation (RQD) And Groundwater Cavity Of The Kuala Lumpur Limestone Formation

by

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Declaration

I hereby declare that I have conducted, completed the research work and written the dissertation entitled "Study On The Rock Quality Designation (RQD) And Groundwater Cavity Of The Kuala Lumpur Limestone Formation". I also declared that it has not been previously submitted for reward for any degree or diploma or other similar title for any other examining body or university.

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LIST OF SYMBOLS

° Degree

' Minute

" Second

m meter

N North

E East

S South

W West

LIST OF ABBREVIATIONS

HKL	Hospital Kuala Lumpur
KBN	Kolej Bersepadu Nasional
ESC	Esd Satellite Centre
RQD	Rock Quality Designation
MRT	Mass Rapid Transport

ABSTRAK

Litologi ditakrifkan sebagai jenis batu dan tanah (Kong, 2017). Data geofizik, permukaan, dan bawah-permukaan tanah termasuk dalam model geologi 3D. Penyelidikan ini dijalankan di Kuala Lumpur, Malaysia dan terbahagi kepada tiga (3) kluster iaitu HKL, KBN dan ESC. Objektif penyelidikan ini adalah untuk mengkaji Penetapan Kualiti Batuan (RQD) pembentukan batu kapur, untuk menyiasat potensi rongga air bawah tanah dan untuk mengaitkan Penetapan Kualiti Batuan (RQD) dengan pembangunan rongga air bawah tanah. Data yang diterima adalah dalam bentuk format pdf dan akan ditukarkan kepada format excel untuk digunakan dalam perisian komputer. Penetapan Kualiti Batuan (RQD) dan informasi lithology kemudian dibandingkan menggunakan graf di dalam excel. Kemudian data yg diberikan akan digunakan untuk membuat 3D model menggunakan perisian visual KARSYS dan distribusi spasial menggunakan perisian Arcmap. Akhirnya, terdapat 16 lubang yang mempunyai rogga air bawah tanah setelah dikenal pasti dan terletak di kluster HKL dan KBN sahaja. Tiada rongga air bawah tanah di kluster ESC. Dan dapat dikonklusikan bahawa semakin tinggi nilai Penetapan Kualiti Batuan (RQD), semakin tinggi peluang untuk terjadinya rongga air bawah tanah. Zon sesar KL wujud di kawasan kajian. Dalam cuaca tropika dan lembap di Malaysia, batu kapur membentuk kars. Oleh itu, cuaca tempatan boleh mempengaruhi jenis litologi. Objektif penyelidikan telah dicapai. Rongga boleh menyebabkan keruntuhan terowong, jalan raya, atau struktur. Oleh itu, sebelum memulakan projek, bawah-permukaan tanah geologi haruslah diselidiki.

Study On The Rock Quality Designation (RQD) And Groundwater Cavity Of The Kuala Lumpur Limestone Formation

ABSTRACT

Lithology is defined as rock and soil type (Kong, 2017). Geophysical, surface, and subsurface data are included in 3D geological models. The research was conducted in Kuala Lumpur, Malaysia and are divided into 3 cluster which area HKL, ESC and KBN. The objectives of this research were to study the Rock Quality Designation (RQD) of the limestone formation, to investigate potential groundwater cavity and to correlate the Rock Quality Designation (RQD) with the development of karst. The problem statement of this project are the presence of karst and the location of water inrush. The data received was in pdf format and converted it into excel format so that can be used into software. Then RQD value and lithology information are compared by using excel chart. Next, use the data given to create 3D modelling using visual KARSYS software and spatial distribution using Arcmap software. Finally, there were 16 boreholes with cavities that were only found in HKL and KBN. There are no cavity borehole in ESC cluster. It can be concluded that the higher the RQD value, the greater the likelihood of karst formation. Limestone forms karst in Malaysia's tropical and humid climate. As a result, lithology types can be influenced by the local weather. The research objectives were achieved. A cavity could cause the failure of a tunnel, road, or structure. Thus, prior to starting any project, learn about subsurface geology.

CHAPTER 1

INTRODUCTION

1.1 Research Background

Water inrush has been identified as one of the most significant geological dangers in underground engineering, resulting in numerous fatalities, financial losses, and environmental harm. A quick and frequently overpowering influx of water entering mine workings is defined as a water inrush. Water inrushes may be triggered by colliding with unforeseen waterlogged ancient workings that were maybe depicted incorrectly on mine drawings. Faults have also resulted in significant water inflows. When talking about water inrush, it's important to first figure out what produces it.

It is risky to leave the water inrush without taking any precautions. The railway track, which runs along Sungai Buloh - Serdang - Putrajaya, is MRT Corp's second in Kuala Lumpur. The objectives of this study are to investigate the characteristics of karst in the investigated area, to create a 3D model of the investigated area using the visual KARSYS software, and to investigate the relationship between karst and subterranean water in the investigated area.

This research was conducted in the Kuala Lumpur area of Malaysia. Essentially, three clusters are involved in this research are Nasional (KBN), Hospital Kuala Lumpur (HKL), and MRT SSP Escape Shaft 1 (ESC) are the three clusters The latitude and longitude for KBN is $3°11'44\text{N}\ 101°44'00E$.Next, the latitude and longitude for HKL is $3°10'15\text{N}\ 101°42'06E$. Lastly, the latitude and longitude for ESC is $3°08'43\text{N}\ 101°42'31E$. **Figure 1.1** show the location of study area.

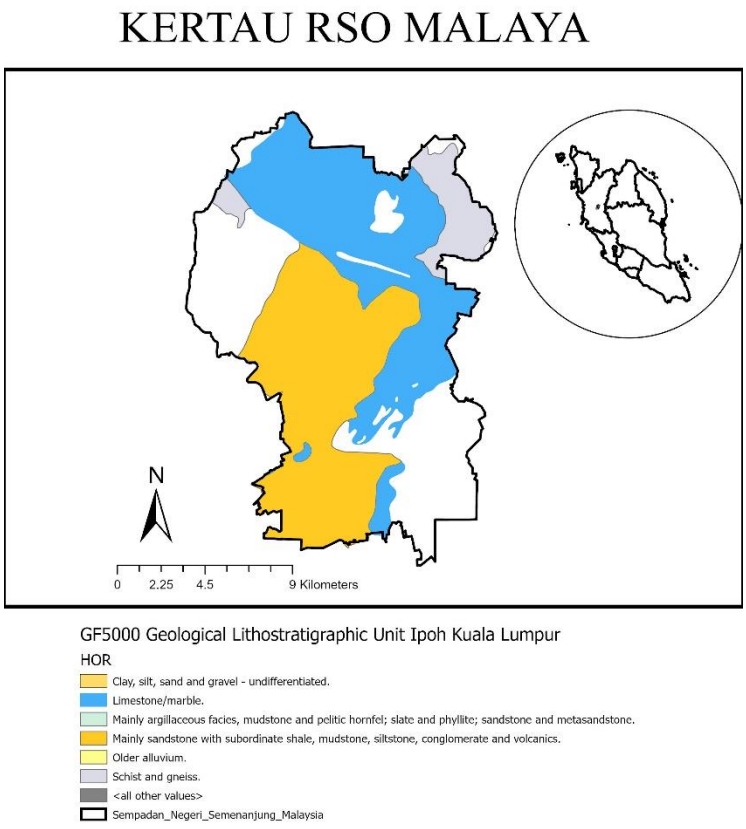

Figure 1.1 Location of study area

All this cluster consists of 82 boreholes and each cluster has different number of boreholes. There are three map that has been create by using the ARCGIS which are **Figure 1-1** show Geological Map of Peninsular Malaysia with study area. Meanwhile, the type of lithology will be discussed in chapter 4. The location of study area was choosen in Kuala Lumpur as the location of MRT is located at Kuala Lumpur. The study area is divided into 3 cluster is to ease the progress of the study.

The approach was presented in Chapter 3 of this study, and it involved the process of using data to create a 3D geological model. The visual KARSYS software was used to create the 3D subsurface model in this study. The visual KARSYS

program is the industry standard for surface and subsurface data visualisation in the petroleum, environmental, geotechnical, and mining industries, with tools like maps, logs, cross sections, fence diagrams, solid model, and volume calculations. Visual KARSYS is a web program that is currently in development for exploring, documenting, and managing groundwater resources in karst aquifers. Users can utilize the web tool to implement KARSYS (Jeannin et al. 2013) on their own to solve specific problems (construction, water supply, geothermic, natural hazards, etc.). At the same time, it allows end users to access and analyse the documentation generated on a particular site. As a result, the software provides a beneficial feature to the user in a variety of tasks.

1.2 Problem Statement

Quantitative modelling of geological processes requires an understanding of the spatial organisation of subsurface formations. It is also necessary for a wide range of human activities, including hydrocarbon exploration and production as well as environmental engineering. Because direct access to the subsurface is only available through digging holes and tunnels, the majority of this knowledge has had to come from various indirect acquisition methods. The goal of 3D subsurface modelling is to improve data interpretation by visualising and confronting data with each other and with the model being built, as well as to generate support for numerical simulations of complex phenomena (e.g., earthquakes, fluid transport) in which structures play an important role.

The location of water inrush is the main problem for this investigation. The 3-D modelling, which was done with the visual KARSYS software, assisted us in determining the location of the karst. But it's important to remember that not all karsts

have water inrush. The Mass Rapid Transit (MRT) project, which includes underground work, was used to conduct the investigation. The majority of the research region is made up of limestone bedrock, which may easily be carved into a cavity. Cavity formation could result in the structure or MRT collapsing. We can see a region that may have a negative impact on the area by creating a 3D model.

Various studies have been conducted to see how a 3D subsurface model might aid in enhancing subsurface geology knowledge and precise mapping. It's because it's required for the design of subsurface engineering constructions including building foundations, road construction, and tunnel construction. However, technology at the time was not as advanced as it is today. The geologist previously employed Geographic Information Systems (GIS) and Computer-Aided Design (CAD) systems, which provide new 3D capabilities and are crucial in the display and processing of subsurface geological data. The initial attempts to use 3D GIS in geological and geotechnical engineering also began with external software developed in the mining and oil and gas industries. There is now a plethora of software available for studying geologies subsurface. As a result, there are no concerns about how geology's subsurface can be interpreted.

Finally, according to de Rienzo, Oreste, and Pelizza (2008), interest in the subsoil in urban areas for the planning and design of new civil infrastructure has led to advances in digital visualisation and 3D modelling techniques suitable for representing a volume of ground and its geological and geotechnical properties. As a result, a 3D model that is suited for civil planning in urban regions and technical applications. A stratigraphical analysis, a geotechnical parameter evaluation, a back-analysis of observed displacement, and model management using a geographic information system are all part of the research (GIS). Any unanticipated geological

condition in subterranean excavations can result in longer construction schedules and costs, increased worker dangers, irreversible environmental harm, and surface settling issues.

1.3 Objectives

- To study the Rock Quality Designation (RQD) of the limestone formation
- To investigate potential groundwater cavity
- To correlate the Rock Quality Designation (RQD) with the development of karst

1.4 Thesis Outline

Introduction, literature review, methodology, result and discussion, and conclusion and recommendation are the five chapters of this study. The introduction, problem statement, aims, and thesis framework are all found in Chapter 1. The problem statement for this study will go into greater detail about the existence of water inrush and how to deal with it.

In chapter 2, the literature review for the research's title is discussed. This chapter will go more into how water inrush affects groundwater quality. Water inrush has a number of harmful consequences. If water inrush under the earth is not treated, the ground's stability can be jeopardised. The types of rock in the researched location that cause the formation of karst is also studied in Chapter 2. We utilise 3-D modelling because it allows us to pinpoint the area of karst and, as a result, the exact site of water inrush.

The methodology that could be employed in this study was covered in Chapter 3. The methods used in this study included using visual KAYSYS software to create a

3D lithology model. Every stage is discussed in greater depth till the 3D model is created. This chapter also includes a flowchart for creating a 3D model.

The research results and discussion are discussed in Chapter 4. The research's findings, such as the 3D lithology model, 3D multiple strip logs, strip log cross section, lithology profile, and more. Furthermore, the 5Ws (what, why, who, when, and how) will be used as a guideline to discuss the findings in greater depth in this study.

Finally, Chapter 5 concludes with a recommendation. It involves discussing the general conclusion of all the working study, either from a theoretical or modelling standpoint. There are also some recommendations that are valuable and can be used in future study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Kuala Lumpur is one of Malaysia's busiest cities. Recent engineering advances in the Kuala Lumpur city, have prompted engineers and scientists to consider the ground qualities that serve as the basis for engineering projects. Three main geological types underpin Kuala Lumpur: limestone (also known as Kuala Lumpur Limestone), granite, and the Kenny Hill formation (Zainuddin Md Yusoff, 2016).

Kuala Lumpur is the capital of Malaysia. Kuala Lumpur is made up of limestone, which is a sedimentary rock that has been intruded by igneous rock (granite). Limestone is made up of sedimentary rock (limestone) and low-grade metamorphic rock (low-grade metamorphic rock) (dolomite). The Kenny Hill formation is a metamorphic rock formation made up of schists, phyllites, and other metamorphic rock types that resulted from the metamorphism of shale, sandstones, and other sedimentary rocks. The majority of the Kuala Lumpur area is covered with limestone (Zainuddin Md Yusoff, 2016).

Limestone is a form of carbonate sedimentary rock that is quite common. Calcite and aragonite, two distinct crystal forms of calcium carbonate, make up the majority of it (CaCO3). Limestone is formed when these minerals precipitate out of dissolved calcium-rich water. This can occur through both biological and nonbiological mechanisms, while biological processes, such as the buildup of corals and shells in the water, are thought to have had a larger role over the last 540 million years. (Sam Boggs, 2006) Fossils are frequently found in limestone, and they supply scientists with knowledge about past habitats and life evolution (Tracy, Robert J. ,1996).

The degradation of rock by physical, chemical, or biological processes is known as weathering. The amount of rainfall is even more important than carbon dioxide concentration in terms of weathering rates. Karstification, the production of limestone caves and other structures, occurs at the quickest rate in the world's wettest locations (Paul Williams, 2007). The majority of limestone dissolution occurs just beneath the soil surface. Soil bacteria produce the most carbon dioxide here, hence percolating water has the highest carbon dioxide level. Dissolving can occur in the top 10 metres or so of the limestone outcrop for up to 90% of the time (Paul Williams, 2007). The epi karst is the extensively eroded rock layer beneath the earth.

The problem arises when limestone beneath Kuala Lumpur begins to dissolve, resulting in karst formation. The problem becomes even worse when most of the karst is created beneath MASS rapid transit's rail track. This could have an impact on the ground stability beneath the railway track. The MASS rapid transit (MRT) system is a passenger rail system that operates in urban areas. Other names for it include mass transit, subway, underground railway, and metro. An MRT system's key feature is its ability to efficiently move large groups of people, and it serves as the backbone of a city's public transportation system, alongside other rail-based modes such as light rail transit (LRT) systems, trams, monorails, and commuter trains.

Since the types of rock under the rail track of MRT is limestone by most. MRT has been given reports on borehole they made under their rail track. The location has 3 cluster which are Kolej Bersepadu Nasional (KBN), Hospital Kuala Lumpur (HKL) and MRT SSP Escape Shaft 1(ESC) with latitude and longitude $3°11'44\text{N}\ 101°44'00E$, $3°10'15\text{N}\ 101°42'06E$ and $3°08'43\text{N}\ 101°42'31E$. These three clusters have possibilities of the presence of karst.

2.2 Geology of Kuala Lumpur

Kuala Lumpur, Malaysia's capital city, was an ideal case study of urban geology due to its rapid development over the last two decades, as well as its importance as the country's major urban center. The numerous construction projects in the Kuala Lumpur area, such as high-rise buildings, housing development schemes, and highways, provide many case histories of engineering and geological problems encountered in this city. Several researchers, including engineering geologists and geotechnical engineers, have since studied and published their findings on the various engineering geological aspects of Kuala Lumpur.

The Kuala Lumpur area was characterized by the appearance of a flat alluvial plain (the Klang Valley) bounded on the east and west by predominantly granitic ranges. The valley floor is composed of extensive limestone bedrock that is overlain by alluvial deposits. In the northern areas of Kuala Lumpur, there is an isolated limestone hill known as Batu Caves, as well as several other hillocks formed by the Hawthornden and Dinding schists (T. B. Kong and Komoo, 1990). The overlying Kuala Lumpur Limestone Formation is made up of fine to coarse-grained, white to grey, majorly recrystallized limestone, with local developments of dolomitic limestone and dolomites, and contains few impurities. The Hawthornden Formation (Middle Ordovician to Middle Silurian) was at the bottom of the sequence, and it was overlain by the Kuala Lumpur Limestone Formation (Middle Silurian to Lower-Middle Devonian) (Gobbett, 1964). The Hawthornden Formation consists of quartz-mica amphibolite, carbonaceous schists, phyllites, and quartzites (Zabidi and Freitas, 1990). **Table 2.1** shows the geologic formations in the Kuala Lumpur area.

Table 2.1 Geologic formations in the Kuala Lumpur area (Yin, 1976).

Age	Formation
Quaternary	Alluvium
Mesozoic or Younger	Granite and allied rocks
Permo-Carboniferous, perhaps Triassic Middle-Upper	Kenny Hill formation (quartzite and phyllite)
Silurian, perhaps Devonian	Kajang Formation (schist and minor limestone, and phyllite)
Middle-Upper Silurian	Kuala Lumpur Limestone; Hawthornden Formation (schist and phyllite)

2.3 Lithology

Engineering geology was concerned with three fundamental studies or issues: lithology or rock type, geological structures, and weathering grades. According to Kong (2017), lithology originally referred to rock type. However, because superficial soils are also important in construction, lithology would include rock and soil types, as well as material types. The first consideration was lithology, because different rock types and, similarly, soil types will have different properties and behaviors. Furthermore, lithology refers to the parent material's overall physical characteristics, such as mineral composition, color, and grain size (Gray & Bishop et al. 2016). Granitic rocks, for example, differ from shales and schist. Limestone was another type of rock that has different features. Because the rock types mentioned above differ in nature and origin, the inherent geological structures associated with each rock type differ as well.

Other urban and hillside development problems include landslides in their broadest definition, involving both rock and soil materials, including man-made fill, mine tailing and colluvium, in addition to the creation of limestone bedrock and limestone cliffs in the Kuala Lumpur and Ipoh areas. The researcher represents several case studies on engineering geology in Malaysia, such as foundations in limestone

bedrock, limestone cliff stability, rock slope stability, dams, tunnels, urban geology, and many more. Therefore, even for simple housing projects near hill slopes, the fundamentals of engineering geology, namely lithology (material type), structure, and weathering, are necessary inputs in various studies on urban and hillside development.

2.4 Identification of lithology

Identification of lithology has always been a fundamental and critical issue in geology, geology resource exploration, geotechnical engineering investigation, disaster prevention and control in tunnel and underground engineering (Xu et al., 2021, 2020, 2019). There are two types of traditional lithology identification methods. One method was direct observation, which involves identifying the lithology by directly observing hand specimens of rocks or rock thin sections. Rocks can be classified into several general categories based on their color, structure, and mineral crystallinity (Hu et al. 2013). The other method was to conduct an experimental analysis using geophysical or geochemical methods. The lithology can be identified using the electrical method, the magnetic method, the scanning electron microscope and electron probe method, X-ray analysis, and isotope analysis, based on information about rock density, magnetism, conductivity, mineral composition, and element content (Fu et al., 2017; Xia et al., 2010).

With the rapid development of computer technology, particularly machine learning and data analysis, increasing automation and low experiment cost have enabled the widespread application of artificial intelligence in a variety of fields in recent years (Ambagtsheer et al., 2020; Ibrahim et al., 2020). The availability of artificial intelligence, particularly deep learning, begins to see use in lithology identification (Xu and Zhou 2018). The traditional deep learning method is capable of automatically

learning the color, shape, texture, and other features of rocks required for lithology identification, resulting in intelligent lithology identification.

Singh et al. (2010), for example, extracted 27 features from images of basalt thin sections to classify images of 140 rock samples. Patel and Chatterjee (2016) extracted color, shape, and texture features from limestone images and fed the data into the Probabilistic Neural Network (PNN), yielding relatively satisfactory limestone classification results. Due to the success of the machine learning method, rock features are still extracted manually (Qi Xing et al., 2018), so researchers began to use deep learning models to automatically extract feature information from rock images and deep learning for intelligent lithology identification.

2.5 Geological structures

Within Kuala Lumpur, the structural setting was complex. To the north-west was Malaysia's western structural belt, and to the west was the Bentong-Raub Zone of subduction (Khoo and Tan, 1983; Metcalfe, 2013). During the Cretaceous, the subvertical Klang Gates Quartz dyke was intruded along a 300 to 320 m trend, associated with the Kuala Lumpur Fault Zone, north of Kuala Lumpur (Shuib, 2009).

2.6 Fault zone

A fault zone was a zone of sheared, crushed, or foliated rock in which numerous small dislocations occur, resulting in a significant total offset on the undeformed walls (Song et al., 2007). Dissolution zones, fault zones, and lithological contacts between the Kuala Lumpur Limestone and the Kenny Hill Formation are frequently associated with sinkholes and earth subsidence (Tan 1987, Gue and Tan 2001). This underlines the need for a low-cost, quick-to-use tool that can precisely map the terrain factors that

contribute to natural hazards and predict their occurrence. Remote sensing allows for the identification and mapping of the most important factors linked to unpredictable environmental and geotechnical engineering problems like flooding, landslides, sinkholes, earth subsidence, and building collapse.

The earthquake was one of the world's most destructive natural disasters. Ground shaking, surface faulting, and liquefaction earthquake events' most common serious consequences (Marto & Adnan et al., 2011). Flooding, landslides, sinkholes, and earth subsidence have been studied for decades using aerial photo interpretation and geophysical survey, but integration of remote sensing and Geographic Information System (GIS) for predicting the occurrence of sinkholes and earth subsidence in Kuala Lumpur city center, Malaysia, has been uncommon. As a result, using different remote sensing data, it is necessary to specify the weight of the most contributing parameters toward natural hazard in Kuala Lumpur (Elmahdy and Mostafa, 2013).

2.7 Three-Dimension Model (3D Model)

The mining industry has long used three-dimensional (3D) interpretation of subsurface properties. The visualization of 3D characteristics was done using twodimensional (2D) specialised maps, cross-sections, and fence diagrams before the development of state-of-the-art computer software. Using 3D Geoscientific Information Systems (3D GSIS), which have effective data management capabilities, it is now possible to easily generate 3D subsurface models (Rahman et al. 2007). The usage of computer software has improved the quantity of 3D subsurface modelling investigations during the last two decades (Renard & Courrioux et al. 1994, de Kemp et al. 2000; Xue et al. 2004; Feltrin et al. 2009; Ming et al. 2010, Akiska et al. 2010).

The interpolation techniques of the software applications are used to create highdefinition 3D models. Furthermore, the location of underground mines and their formation conditions can be detected (Akiska, Sayili and Demirela, 2013). The primary goal of 3D modelling of ore deposits was to establish the complicated geological, structural, and mineralogical conditions that exist in these regions, as well as to locate the deposits in the subsurface environment. Recent 3D subsurface modelling studies have provided some insight not only into finding mineral sites, but also into the formation conditions of the deposits (Feltrin et al. 2009).

2.8 Rock Quality Designation (RQD)

A borehole's rock core is graded according to its quality using a system called Rock Quality Designation (RQD). RQD is a percentage that indicates how much jointing or fracture there is in a mass of rocks; an RQD of at least 75% indicates high-quality hard rock, while an RQD of less than 50% indicates low-quality weathered rocks. A rock core sample from a borehole is used to compute RFQ. The lengths of all sound rock pieces that are at least 100 mm long are added up, and the result is divided by the length of the core run. Only rocks that are hard and of high grade are taken into consideration. Weathered rocks that don't exceed soundness standards and whose lengths are less than 100 mm are not taken into account when calculating RQD. The centre line of the core parts is used to measure the length of the pieces. The RFQ test evaluates the soundness of the rock and any weathering-related deterioration.

Additionally, the mining sector uses the rock quality designation (RQD) standard technique for qualitative and quantitative evaluation of the rock quality and level of jointing, fracturing, and shearing in a rock mass. The proportion of complete drill core pieces longer than 10 cm that are recovered in a single core run is known as

RQD (Abzalov, 2016). From the RQD index the rock mass can be classified as in **Table 2.2**:

Table 2.2 Quality of rocks and their RQD

Rock Quality	**RQD (%)**
Very poor (Completely weathered rock)	<25%
Poor (weathered rocks)	25 to 50%
Fair (Moderately weathered rocks)	51 to 75%
Good (Hard Rock)	76 to 90%
Very Good (Fresh rocks)	91 to 100%

RQD is used to assess the quality of rocks by looking at factors such fracture, zones of rock weakness, and the depth and severity of weathering. This data calculates the foundations' depth, the bearing capacity of rocks, and the likelihood of foundation settlement and slide. RFQ assists in establishing ideal tunnelling conditions and identifying areas with low-quality rock that would not be able to sustain engineering constructions.

RQD is a commonly used tool to evaluate the quality of rocks. This test aids in determining the soundness of the rocks and the extent of any weathering-related damage to the rocks. A rock mass's zones of rock weakness and degree of jointing for fracture are also assessed using the Rock Quality Designation (RQD). It is used to calculate the foundation's depth and the rock mass's bearing capability. The term "rock quality designation" (RQD) is frequently used to describe the weak rock zones, which is crucial when building large buildings. The RQD has numerous uses in geotechnical

engineering, engineering geology, and mining. To determine the conditions for tunnelling, the rock quality classification is also used.

The Rock quality label has different values based on the run's direction. The RQD does not provide information on core components that are less than 10 cm in length. Where joints have thin clay fills or worn material, Rock Quality Designation assigns incorrect ratings. does not directly take joint orientation into consideration. Rock-quality designation (RQD), calculated as a percentage of the drill core in lengths of 10 cm or more, is a crude indicator of the degree of jointing or fracture in a rock mass. Rock of high grade has an RQD of greater than 75%, while rock of low quality has an RQD of less than 50%. There are various meanings for "rock quality designation" (RQD).

2.9 Visual KARSYS software

A software platform devoted to managing karst groundwater is called Visual KARSYS. A number of tools available through Visual KARSYS for analysing aquifer geometry and groundwater flow systems. For scientists, engineers, managers, and other stakeholders dealing with environmental challenges in karst environments, such as waste deposits, geothermal heat probes, civil engineering projects, groundwater resource exploitation and protection, etc., Visual KARSYS is made available.

In addition, a web application called Visual KARSYS is being developed specifically for exploring, documenting and managing groundwater resources in karst aquifers. Users can utilise the web tool to independently apply KARSYS (Jeannin et al. 2013) to deal with certain problems (construction, water supply, geothermic, natural hazards, etc.). Additionally, it enables end users to browse and review the resultant content on a relevant site.

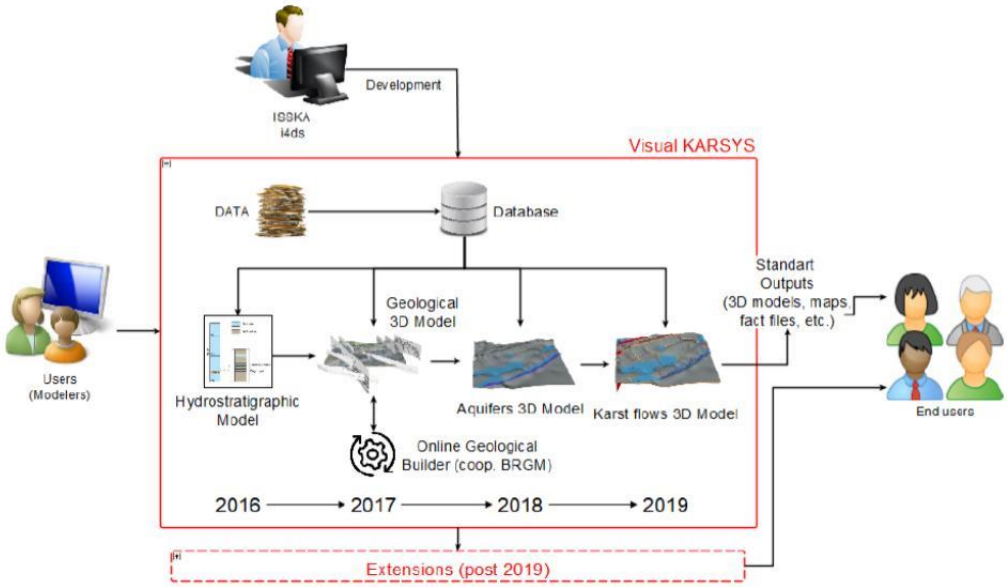

Figure 2.1 Workflow of Visual KARSYS; users (Modelers) can process the successive KARSYS models step by step.

In order to create an online geological builder that could be used with Visual KARSYS, cooperation with the BRGM was done. This is because the use of KARSYS needs the creation of an implicit 3D geological model before modelling aquifers. Users can complete every step of the KARSYS approach using this solution inside of Visual KARSYS. To guarantee data integrity and traceability, geological and hydrological data are combined and linked to the generated models.

The Visual KARSYS project is now being carried out by SISKA and i4ds with funding provided for three years by the Swiss Federal Office for Environment. In the current implementation level, users can start and export a GeoModeller project as a.zip file, which can then be imported with a desktop version of GeoModeller and contains the project's parameters, DEM, maps, cross-sections, and formations.

Cross-sections and DEMs that go over the bounding box of the project are automatically clipped. Progressively implementing additional features (including a

dedicated interface for entering geological data). Users will be able to perform the entire KARSYS workflow through Visual KARSYS by the middle of 2019. Modules relevant to the generation of the 3D models of the aquifers and of the groundwater flows will be created in 2018. Specific enhancements like hydraulic flows and recharging simulation will be added after 2019.

2.10 ArcMap software

The centrepiece of Esri's ArcGIS family of geospatial processing applications, ArcMap is primarily used to examine, modify, produce, and conduct analyses on geospatial data. With the use of ArcMap, a user can study data included inside a data set, symbolise features appropriately, and produce maps. The data frame and the table of contents, two separate software parts, are used to accomplish this. It was revealed in October 2020 that there would be no 10.9 update in 2021[2] and that ArcMap would cease to be supported on March 1, 2026. Users are being encouraged by Esri to switch to ArcGIS Pro.

Users of ArcMap can create and modify data sets to contain a variety of data. For instance, ArcMap maps typically have elements like north arrows, scale bars, titles, legends, crisp lines, etc. A style-set of these characteristics is included in the programme package. Additionally, you can submit a variety of different reference styles to use with any mapping function.

There are four licence types for the ArcGIS suite: Basic, Standard, or Advanced (formerly ArcView, ArcEditor, or ArcInfo), and Pro. With each licence upgrade, the user receives new extensions that enable a wider range of queries to be run on a data source. Pro is the highest level of licencing, and it entitles the user to access various

additional functions with each new edition, as well as extensions like 3D Analyst, Spatial Analyst, and the Geostatistical Analyst.

2.11 3D Modelling Analysis

According to Carvalho (2020), 3D geological models are important for mineral discovery since they could assist clarify the tectonic and deposition patterns in the area being studied. Additionally, it is used to identify ore-bearing fluid migration routes, map out alteration zone patterns, and pinpoint areas where minerals might be deposited in commercially viable quantities. Geologic mapping is a valuable data source because it offers a wealth of details that are essential for the discovery of new mineral deposits and subsequent exploitation. Through the geologic mapping of outcrops, the basic lithology and shape of rock bodies, as well as age relationships between rock groups, are characterised (G.H Brimhall & J.H. Dilles et al. 2005).

Geological models serve as constraints and help generate fresh exploration prospects during the geophysical modelling process. The outcome was a thorough 3D model of subsurface geology that incorporates all information available and may be applied to more mining exploration. In summary, incorporating all geological data into a 3D model significantly benefited 17 in the interpretation and confirmation of anomalies of different physical natures and may prove valuable in future exploratory activity, should one be required.

Furthermore, a 3D model must be used to accurately comprehend and map the underlying geology for projects involving underground engineering, such as the design of building foundations, roads, and tunnels. Geologists used to construct subsurface geology manually, which required a lot of time and work. After ten years, a lot of software and technology have been created. Software that has been used includes

computer-aided design (CAD) and geographic information systems (GIS). These two programmes can represent and handle subsurface geological data in 3D and have a large amount of 3D capacity.

For the majority of earlier studies, 3D geological modelling was employed to explore for and produce hydrocarbons. In the early attempts to use 3D GIS, external software developed in the mining and oil and gas industries was also utilised. Then, around the turn of the century, there were high expectations for the widespread adoption of 3D GIS in geological and geotechnical engineering for subsurface mapping. Nevertheless, despite several studies proving the value of 3D GIS for tunnelling projects, uptake has lagged behind expectations.

Furthermore, is crucial to comprehend the thermal and hydraulic conditions beneath significant urban centres in the context of energy and water supply. In Berlin's major urban regions, the shallow water to deep groundwater interactions were being studied by the geologists to learn more about how surface water bodies are connected to the underlying thermal and hydraulic system. The geologists developed a 3D structural model of the subsurface that was constrained by all the information and observations that were available in order to simulate the coupled flow of fluid and heat. Geologists can investigate deep-to-shallow interactions as depicted in various model scenarios thanks to the 3D model, concentrating on changes in local hydrodynamics brought on by varied, realistic representations of the upper hydraulic boundary condition (Frick et al., 2019).

On the other side, Schokker (2015) presented a study that used 3D subsurface modelling to show the shallow geology of Amsterdam. According to the study, the shallow subsurface beneath the city was composed of more than 10 metres of unconsolidated Holocene deposits, including peat, clay, and loosely packed fine to

medium-grained sand. Ground sinking has continued as a result of city growth and associated water system modifications, affecting structures and infrastructure. A substantial network of pipes and cables for sewage, drinking water, gas, electric, and other utilities are located in the subsoil, along with parking and underground infrastructure (Kranendonk et al. 2015).

Not only can a 3D model be created to evaluate subsurface geology, but it also illustrates, in this case, how a geologist might interpret the region using a 3D fence diagram. Ground-based heat pumps can also get their energy from the subsoil, which also acts as a reservoir for groundwater. To ascertain the extent and depth of the foundation levels that have been utilised for structures in the city centre as well as to identify the source of filling sand on which the city's more recent growth was in fact largely based, a new geological map of the study area is created using 3D models.

De Rienzo, Oreste, et al. (2008) also looked at the use of 3D subsurface geological and geotechnical modelling to optimise the planning and building of subsurface buildings in the Turin, Northern Italy, city region. A wide amount of ground can be shown using the 3D modelling technique. It can reveal not just how much ground is present but also the area's geological and geotechnical characteristics. Due to the significance of subsurface town planning as a resource for city expansion, subsurface modelling necessitates a multidisciplinary approach.

A spatial model that depicts the distribution of sediments and the variation in their physical and geomechanical properties. This information is crucial for a number of applications, such as the evaluation of natural hazards, the planning of underground construction projects, and hydro-geological studies for aquifer recharge. The difficulty in obtaining subsurface data and their heterogeneity, which comprised stratigraphic boreholes, penetration tests, drilling records, and other criteria, seem to be the main

causes of any uncertainty regarding the geological conditions in city subsurface modelling. As a result, optimising the design of civil works now necessitates a multidisciplinary approach to data analysis.

Construction of railroads, highways, and urban rail transit is all hampered by more challenging geological conditions. It is challenging to properly understand the geological environment for more reasons than one. However, complex geological events, boundary conditions, and geological structures can be completely and accurately depicted using the 3D geological model. Additionally, it can enhance the clarity and intuition of geological analysis. Engineers can more effectively match engineering design and construction plans with the actual distribution and variation of geological phenomena thanks to these advantages, which also reduce project risks. The research combines the spatial analytic capabilities of a 3D model to build an efficient approach for 3D visible geological information analysis. Additionally, it aids in creating a realistic route design (Kavoura et al., 2016).

Finally, 3D geological models make it possible to determine the best field development alternatives and lower exploration risk (Labourdette et al. 2008; Gundeso & Egeland 1990). Due in part to the utilisation of 3D seismic surveys by industry, two technological advancements have significantly advanced subsurface visualisation (Fernandez et al. 2004). One of the most accessible data sources for creating 3D models is geological survey records. Examples include boreholes, outcrop or structural data gathered during fieldwork, geological maps, and cross-sections (Kauffman and Martin et al. 2008). Geologists will continue to make geologic observations and interpretations as the capability to see traits that were previously invisible to the naked eye improves. Geologists integrate a variety of data and knowledge sources to undertake interpretations over sparsely populated areas.

As a result, it appears that no one modelling tool or piece of software can store, publish, and alter everything that is needed. Combining GIS technologies, 3D modelling software, and the right database will enable scientists to create comprehensive and pertinent 3D geology models. Testing alternative methods and finding limitations in the modelling process as well as data gaps remain crucial research topics in the geospatial or geoscience world of today (Qi et al., 2007).

CHAPTER 3

METHODOLOGY

3.1 Introduction

Several spatial interpolation algorithms, such as nearest neighbours, inverse distance weighting (IDW), kriging, and triangulated irregular network-related interpolations, are employed in surface and subsurface modelling software (Li & Heap et al. 2008). Each software application has its own set of benefits and drawbacks, but they all contain nearly all of the interpolation methods utilised in modelling research (Rahman et al. 2007). The visual KARSYS software was used to carry out the modelling in this study.